Review of Nonpoint Source Pollution and Best Management Practices Along the South Carolina Coast

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REVIEW OF NONPOINT SOURCE POLLUTION AND BEST MANAGEMENT PRACTICES ALONG THE SOUTH CAROLINA COAST

Introduction

Studies of nonpoint source pollution, the legal aspects of storm water legislation, and urban best management practices were reviewed to determine that the best techniques are being used to control nonpoint source pollution in Charleston and other coastal areas. Comprehensive information was obtained through literature reviews at Clemson University's Cooper Library, attendance at The American Society of Civil Engineers (ASCE) Water Forum 1992, attendance at the South Carolina Land Resource Conservation Commission (SCLRCC) workshop "Site Development and Best Management Practices for Stormwater Management and Sediment Control", and personal communications with relevant specialists. Contacts to obtain unpublished and/or up to the date resources include:

- MaryAnn Gerber, Environmental Engineer - United States Environmental Protection Agency (USEPA) Region IV Water Management Division, nonpoint source specialist.
- Marshall Jennings, Civil Engineer/Hydrologist - United States Geological Survey, Water Resource Division, Texas District, detailed knowledge of Nationwide Urban Runoff Program (NURP) studies.
- Earl Shaver, Environmental Engineer, State of Delaware, Division of Soil and Water Conservation, Department of Natural Resources and Environmental Control, pioneered practical design storm water management and erosion control aspects - while at Maryland in a similar position.

- Joe Fersner and Debra Hernandez, Hydrologists/Environmental Engineers - South Carolina Coastal Council, special knowledge of codes, and management practices specific to the coast of South Carolina.

- Chuck Jarman, Capital Project's Engineer, Charleston County, SC, design expertise of coastal best management practices.

- Flint Holbrook, Hydrologist/Civil Engineer, South Carolina Land Resource Conservation Commission, close knowledge of best management practices for storm water management and sediment control.

- Larry McDonald, South Carolina Department of Health and Environmental Control, nonpoint source pollution expert.

- Paul Conrads, Civil Engineer/Hydrologist, United States Geological Survey, Water Resource Division, South Carolina District, coordinator of water quality studies for calibration and verification of water quality models of the Charleston Harbor.

NONPOINT SOURCE POLLUTION

Introduction

Water quality is altered when pollution enters the water. Pollution is defined as a contaminant that has a detrimental effect on the environment. Two types of pollution exist, point and nonpoint source. Point source pollution is defined as pollution discharged from a well-defined location, such as discharges from industrial processing waters or the effluent from sewage treatment facilities. Nonpoint source pollution, the subject of this investigation, is defined as pollution occurring from an ill-defined or diffuse source (SCLRCC 1989).

In 1978, the United States Environmental Protection Agency (USEPA) began a 5-year study of storm water. This study was called the Nationwide Urban Runoff Program (USEPA 1983). The study found that in rivers and streams, the heavy metals water quality criteria for aquatic life is frequently exceeded because of urban runoff. From the analysis of heavy metals, copper, lead, and zinc typically had the highest concentrations. Copper, lead, and zinc, with copper being the most troubling, pose the biggest threat to aquatic life. The study looked at only two sites regarding organic priority pollutants (e.g. pesticides). For this reason, priority pollutants were generalized as being detected less frequently and occurring at lower concentrations than heavy metals.

Nutrients, i.e. total phosphorous, soluble phosphorous, total kjeldahl nitrogen, nitrate, and nitrate were carefully examined. Results indicated that nutrient concentrations in urban storm water runoff occurred at lower rates than in the receiving waters. The study indicated that some sites did record higher values, but this trend was atypical. Some lakes and streams became eutrophic when the nutrient levels were high in urban runoff. Oxygen demanding substances, in urban runoff, were indicated as being present in similar concentrations as effluent from sewer treatment plants using secondary treatment operations (USEPA 1983).

Total suspended solids concentrations in urban runoff occurred at fairly high levels when compared with sewage treatment plant effluent (USEPA 1983). Suspended sediments, from scour and erosion, were found to cause significant habitat disruptions in rivers and streams (Schueler 1987). Coliform bacteria were found to be present in high levels in urban runoff (USEPA 1983). USEPA water quality criteria for fecal coliform was typically exceeded during and immediately following storm events in most rivers and streams.

Based on data from only two sites, groundwater aquifers that received deliberate recharge from urban storm water runoff were not contaminated (USEPA 1983). Further studies should be conducted on the effects of infiltration practices on groundwater aquifers. Travel time to an aquifer is dependent on numerous parameters, (i.e. soil type and layer configurations, depth to bedrock, depth to groundwater table, etc.) which can vary locally and/or regionally.

Congress passed the **Federal Water Pollution Control Act Amendments of 1972** to allow US EPA and the States to control point source pollution with a permitting process called the **National Pollutant Discharge Elimination Systems** (NPDES) permit. The NPDES permit allows the permittee to discharge their point source pollutants as long as it meets the limits established by the permit. The presence of nonpoint source pollution is much harder to detect and regulate, some exceptions do exist (e.g. pesticide application for agricultural practices, etc.).

In November of 1990, Congress approved legislation that requires urban areas and industrial sites to have NPDES permits for all large storm water outfalls. Urban areas are defined as cities with populations greater than 100,000 people and/or counties with greater than 250,000 people. Large outfalls are defined as 36 inch (914.4 mm) or greater diameter pipes for cities and counties, and 12 inch (304.8 mm) or greater diameter pipes for industrial sites (USEPA 1990). Urban area and industrial site storm water runoff is the only nonpoint source pollution that is currently being regulated by NPDES permits.

To improve water quality, by reducing nonpoint source pollution, Congress passed legislation, Section 319 of the **Clean Water Act Amendments of 1987**, which required each state to assess nonpoint source pollution problems and develop a four-year management program for correcting the problems (SCLRCC 1989). The next section will address the problems South Carolina, and the United States, are facing with poor water quality caused by nonpoint source pollutants.

Current Policies in South Carolina

In South Carolina, the agency that is primarily responsible for water quality is the South Carolina Department of Health and Environmental Control (SCDHEC). In addition, the South Carolina Land Resource Conservation Commission (SCLRCC), the South Carolina Coastal Council (SCCC), and the South Carolina Forestry Commission (SCFC) have some water quality responsibilities. These agencies are working in collaboration to comply with the Section 319, of the **Clean Water Act Amendments of 1987** (SCLRCC 1989). In a survey of nonpoint source pollution, the above South Carolina agencies found a total of 336 water bodies (e.g., lakes or ponds) in South Carolina had been impacted. Of these 336 water bodies, 43% were influenced by storm water runoff and another 14% were influenced by construction activities. Forty-seven of those water bodies were determined by SCDHEC to be of top priority (SCLRCC 1989). Data from SCDHEC shows approximately 390 sources of pollutants contaminated the groundwater at thirty-five sites, with about 90% clearly associated with nonpoint source pollution. After assessing the effects of nonpoint source pollution on water quality, SCDHEC has and is forming a plan of action.

A bill sponsored by SCLRCC has made parts of SCDHEC's plan of action become state law. The bill was introduced in the 1989 session of the South Carolina General Assembly (passed and recorded in South Carolina State Register, June 26, 1992). The bill requires all land disturbing activities to be conducted in accordance with storm water management and sediment control plans approved at either the local or state level. Specifically, the bill states that "... [site] plans should include measures for storm water management and sediment control during the land disturbing activity, as well as the maintenance of storm water systems throughout the life of the facility (SCLRCC 1989)." To avoid delays in construction, the bill allows 15 working days for the administering agency to take action on applications, if no action is taken within the 15 working days the plan would become automatically approved. For more information, see the section entitled "Legal Aspects of Storm Water - Current Regulations."

Another part of the plan of action required SCDHEC to write a manual called **Nonpoint Source Management Program for the State of South Carolina.** In this manual SCDHEC established nonpoint source pollution management goals for: agriculture, forestry, construction, urban runoff, mining, land fills, and hydrologic/wetlands modifications. These goals are referred to as best management practices. SCDHEC defines best management practices as storm water management and conservation practices which have been demonstrated to effectively control movement of pollutants, prevent degradation of soil and water resources, and are compatible with the planned land use (SCDHEC 1989b). Also in the manual, SCDHEC states that at the time of writing the manual, more research needed to be done to establish best management practices. SCDHEC stated their belief that a standard method of devising best management practices for all situations could not be provided (SCDHEC 1989b). Furthermore, SCDHEC predicts that education regarding nonpoint source pollution is an important tool in reducing nonpoint source polluting, thereby improving water quality.

Nonpoint Source Pollutants in South Carolina

South Carolina is a state with diverse topography and land use. South Carolina's economy relies on agriculture, construction, industry, forestry, mining, textiles, and tourism. All of the above can contribute nonpoint source pollution that has a negative effect on water quality. The following list is characteristic of nonpoint source pollutants (or measurements of contamination) common to South Carolina's water (SCDHEC 1989a).

- Dissolved Oxygen
- Suspended Solids
- Turbidity
- pH
- Fecal Coliform
- Biochemical Oxygen Demand
- Ammonia
- Total Phosphorus
- Nitrate-Nitrite
- Conductivity
- Iron
- Lead
- Cadmium
- Chromium
- Zinc
- Nickel
- Copper
- Mercury
- DDT
- Aldrin
- Endrin
- Dieldrin
- Toxaphene
- Heptachlor
- Malathion
- Diazinon
- Phosdrin
- Acid Extractable Organics
- Volatile Organics
- Guthion
- Trithion

Agriculture

Agriculture can contribute several different types of nonpoint source pollutants that will alter water quality. Pesticides are used extensively in farming operations. The pesticides then become nonpoint sources of pollution when they are carried to nearby lakes, rivers, or streams during a storm event. Pesticides also migrate through the ground to contaminate groundwater. Agriculture, in South Carolina also consists of raising livestock and poultry. The waste from the animals can act to contribute nonpoint source pollution in storm waters and groundwater. The animal waste is transported into nearby lakes, rivers, and streams during storm events, or infiltrates into the ground to contaminate groundwater supplies. An example of this type of nonpoint source pollution would be the runoff during a storm event that occurs at feed lots or pasture lands (SCDHEC 1989b).

Industry

Industry helps to create nonpoint source pollutants by the emission of point source pollutants into the atmosphere. These emissions are legal but when they are combined with car exhaust, smoke from homes heating with wood stoves, trash fires, forest fires, volcanic eruptions, etc., they form air pollution. When these pollutants become heavy enough, they settle out of the air (like regular dust particles). If moisture is present, the pollution particles will be the nuclei for water droplets. The pollution particles then fall to earth as "acid rain" or "acid fog."

Forestry, Construction, and Mining

South Carolina has a relatively large amount of timber lands available as forest resources. Current forest operations contribute vast quantities of sediment, which in turn degrades water quality. The sediment is transported into lakes, rivers, and streams by erosion during a storm event. Forest operations, agriculture, construction, and mining activities are significant contributors to erosion. For every pound of municipal and industrial waste discharged into our rivers, lakes, and streams, erosion can add several pounds of sediment (USDI/GS 1981).

Controlling Nonpoint Source Pollution

Nonpoint sources of pollution are very hard to locate. This makes a prescribed solution impossible to develop. SCDHEC has decided the best way to control nonpoint source pollution in South Carolina is through education and the implementation of best management practices (SCDHEC 1989b). It is much less expensive to prevent nonpoint source pollution from reaching the water bodies, than it is to treat compromised water bodies to improve water quality.

Some of the educational tools SCDHEC plans to use to disseminate information includes (SCDHEC 1989b):

- The publishing of a nonpoint source pollution control newsletter will be used to inform engineers, environmentalists, and other professionals of "current events" or research associated with nonpoint source pollution.
- A citizen's handbook on nonpoint source pollution is also to be written.
- Plans for seminars and conferences directed at the problems and available solutions for nonpoint source pollution are being made.

- The creation of films, slide shows, and videos targeted to different audiences (adults, children, and youth) should prove useful in detailing the problems and solutions associated with nonpoint source pollution.

- Exhibits and displays at county and state fairs would disseminate information to individuals that were still unaware of the problems and solutions that transpire with nonpoint source pollution.

The other tool SCDHEC has implemented to improve water quality is best management practices. Best management practices for protecting water quality in South Carolina are divided into seven categories by SCDHEC (1989a).

1) Agricultural Activities

- avoiding the spray of pesticides within eighty feet of water bodies
- contour farming
- field borders (that control erosion)
- crop rotation
- grassed waterways
- planned grazing systems
- strip-cropping, and terraces

2) Forest Activities

- better planning of access roads to control erosion
- better harvesting techniques that curb erosion
- service and maintenance of equipment should be performed far away from water bodies (as well as disposal of waste oil and lubricants in a legally designated manner)
- during site preparation make every reasonable effort to leave topsoil in place

3) Construction Activities

- temporary gravel construction entrance/exit (removes mud from construction vehicles before leaving the site as well as stabilizing the entrance from eroding)
- hay bale barriers
- silt fences
- rock check dams
- rip rap lined storm water outfalls
- dust control (use a water truck when dry weather is causing dust problems

4) Urban Storm Water Runoff

- grassed lined swales (typically with 4 horizontal : 1 vertical side slopes)
- rip rap lined ditches
- oil and grease filtering catch basins
- parking lot planting areas
- detention/retention/sedimentation ponds
- pervious asphalt paving
- rock check dams
- silt fences
- hay bales
- street flushing
- street cleaning

5) Mining Activities

- aquifer recharge systems
- buffer zones between mining activities
- contour mining
- controlled drainage
- dust suppressants
- sediment basins with flocculant settling
- geotextiles
- grassed waterway outlet structures
- neutralization
- mulching
- terracing

6) Solid Waste Disposal Activities

- proper landfill placement
- proper operation and maintenance (O&M) plan
- control of runoff and leachate
- incineration with resource recovery
- recycling
- proper erosion control plan
- buffers between landfill and water bodies
- groundwater monitoring

7) Hydrologic/Wetlands Modifications

- select previously used disposal sites
- mix, dilute, and disperse the discharge
- minimize water column turbidity
- avoid changes in water current and circulation patterns
- avoid seasons or periods when human recreational activity associated with the aquatic site is most important

LEGAL ASPECTS OF STORM WATER RUNOFF

History

Riparian Rights

South Carolina water law predates the formation of the United States. Much of South Carolina's water laws have a traceable history that originated in English Common Law. Water rights in South Carolina are based on the Doctrine of Riparian Rights. Riparian Rights are defined as the rights of owners of land adjacent to water bodies (i.e. rivers, streams, ponds, lakes, etc.) to use the water in that water body. The phrase, the right to use, is a keyword for understanding Riparian Rights. All adjacent land owners have the right to use the water in reasonable amounts but the water can not be used to the detriment of other adjacent land owners. Also, there is no priority for the right to use between land owners adjacent to the water body. Omelvany v. Jaggers, 2 Hill 634 (SC 1835); White v. Whitney Mfg. Co., 60 SC 254, 38 SE 456 (1901); United States v. 531.13 Acres of Land, 366 F.xd 915 (1966); and The Riparian Rights Doctrine in South Carolina, 21 SC Law Rev. 757, 770 (1969) are important precedents defining water rights.

Diffuse Water Rights

Diffuse water is defined as runoff water from precipitation, be it snow, sleet, freezing rain, or rain. The statutory regulations controlling diffuse water rights are defined in the **South Carolina Code of Laws §49-3-40** as follows. Diffuse water, in general, can not be confined to establish a stream. Water on land, can be used by the owner, conventionally. Runoff is treated as a "common enemy". The Common Enemy Doctrine allows a land owner to divert runoff so as to protect property. This diversion, however, can not be to the detriment of other land owners (Chapman, 1992).

Irrigation drainage systems are regulated by the **South Carolina Code of Laws §49-13-10**. The regulation of ground water is covered in the **South Carolina Code of Laws §49-5-10 and §49-5-20**. The regulation of wetlands is covered in the **Clean Water Act Amendments of 1987, Section 404** and/or 33 USC **1341** (Chapman, 1992). The regulation of storm water management is covered by R.19-450 (SCLRCC 1992). Regulations pertaining to critical areas of the coastal zone are covered in R.61-101.

Current Regulations

In South Carolina, the newest and most important regulations for storm water runoff appeared June 26, 1992 in the State Register. They are entitled, **Standards for Storm Water Management and Sediment Reduction.** These laws were prompted by the passage of the United States **Clean Water Act Amendments of 1987**. The **Standards for Storm Water Management and Sediment Reduction** establish a procedure and minimum standards required for a statewide uniform program for storm water management and sediment reduction with the option of being operated locally. The regulations are based on permits issued from site plan review and later investigations, which are made to determine that the approved site plans are being followed.

The regulations require that after October 1, 1992, all land disturbing activities greater than 2 acres must meet the minimum standards described in the regulations. If a local agency does not exist as of October 1, 1992, the South Carolina Land Resources Conservation Commission will assume the responsibility as the implementing agency. In South Carolina coastal counties, the South Carolina Coastal Council is vested with this responsibility. Along the coast, any land disturbing activity with in 1/2 mile of a receiving water body is required to receive a permit. There are some small counties that will be allowed to "continue as normal" until fiscal year 1994-1995.

In the **Standards for Storm Water Management and Sediment Reduction** §72-307 states that best management practices should be used to control sediment and water quantity/quality. §72-307 C) 4 a) states that, "Post-Development peak discharge rates shall not exceed pre-development discharge rates for the 2 and 10 year frequency 24-hr duration storm event." This parallels results obtained from studies by the Maryland Water Resource Administration (MWRA) and other leading agencies. A modeling analysis was used in which MWRA determined that if both the ten-year and two-year design storm events were used in the design of best management practices, then the whole range of expected storm reoccurrence intervals could be adequately controlled (MD WRA 1986).

CATEGORIES OF URBAN STORM WATER BEST MANAGEMENT PRACTICES

There are two categories of urban storm water best management practices - structural and nonstructural. A structural best management practice is one that must be constructed. An example of structural best management practices is the construction of a detention/retention pond to control storm water runoff quality/quantity. A nonstructural best management practice is a regulation or guideline that is enforced so that the control of water quality/quantity can be improved. An example of this might be a local ordinance or regulation for the disposal of used motor oil. Best management practices are needed as a result of changes in the watershed hydrology due to urbanization (see Figure 1).

As seen in Figure 1 a), "Water Balance", urbanization reduces vegetation and increases impervious area, which in turn reduces transpiration, interflow, and baseflow, but increases surface runoff. In Figure 1 b), "Streamflow", urbanization increases peak discharge rates but decreases baseflow rates. In Figure 1 c), "Response of Stream Geometry", urbanization raises the floodplain limit but decreases the summer low flow level. Best management practices are used to counter the effects of urbanization on the hydrology of a watershed.

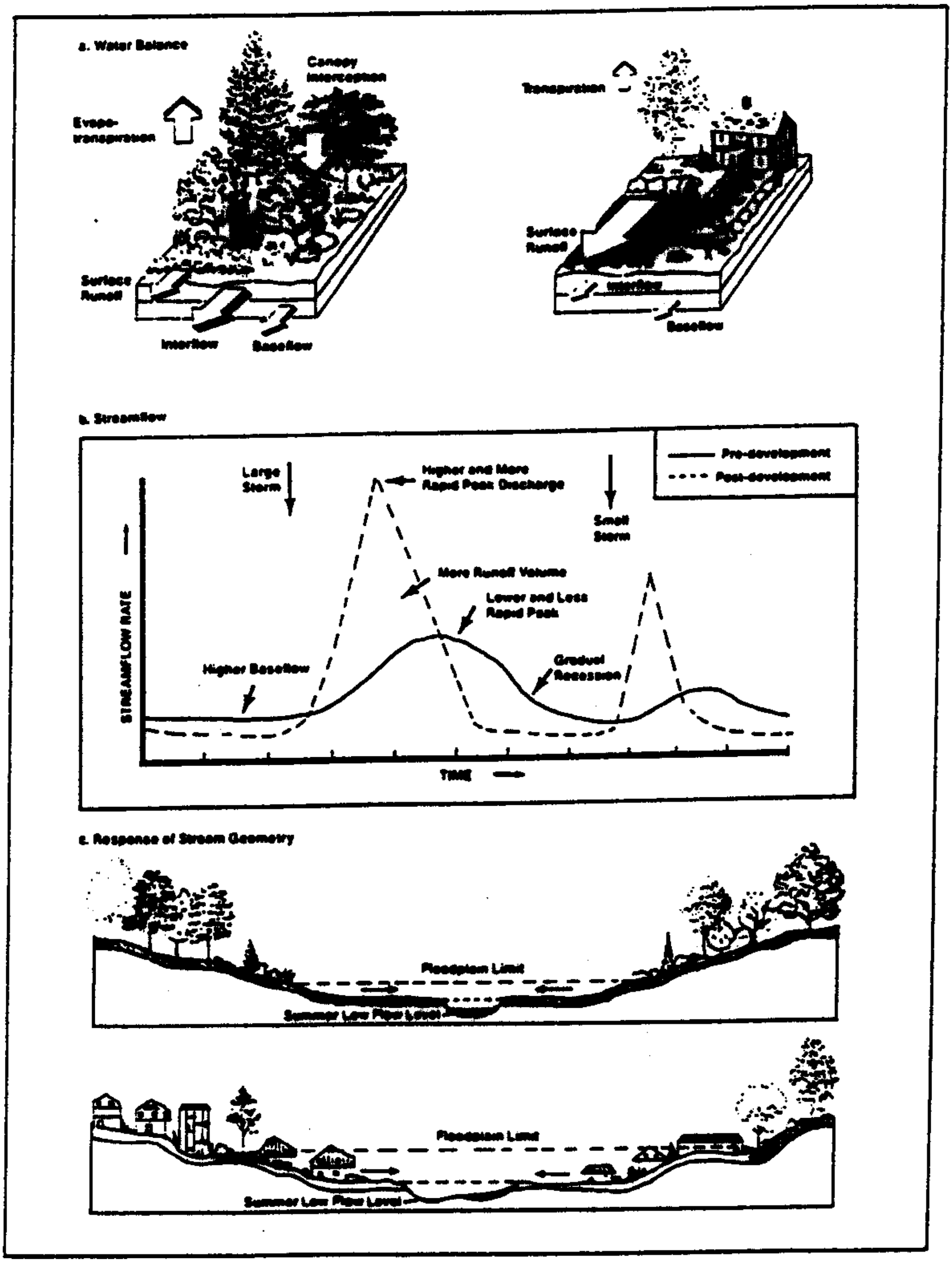

Figure 1. Changes in Watershed Hydrology due to Urbanization (Source: Schueler 1987)

Structural Best Management Practices

Structural best management practices can be broken down into seven important categories:

- Detention Ponds
- Retention Ponds
- Infiltration Basins
- Infiltration Trenches
- Porous Pavement
- Water Quality Inlets (oil and grease removal)
- Vegetative Systems.

A discussion of the management practice, a summary of the associated efficiencies, if available, as well as highlights of the advantages and disadvantages of each category follow.

Detention Ponds

Detention ponds act as a permanent storm water management structure, with the primary purpose of temporarily storing storm water runoff and releasing it at a controlled rate (SCLRCC 1992). A detention pond's storage pool is usually dry before a storm event (see Figure 2).

If detention ponds are designed such that the storage time is extended, then a high level of particulate removal can be achieved. This is important because many contaminants are removed by settling. The detention pond with extended storage time (for short, extended detention pond) does not remove soluble pollutants, such as ammonia, and orthophosphate. The information defining approximate percent removed (see Table 1) is available from the Occoquan Watershed Monitoring Laboratory (OWML 1983). These data are based on both field and laboratory settling column observations. The settling data are an average of seven column tests, which matched well with field measurements. The pollutants studied were: total suspended sediments (TSS), lead (Pb), zinc (Zn), chemical oxygen demand (COD), total phosphorous (TP), and total nitrogen (TN). Unfortunately, extended detention ponds were not evaluated in the NURP (EPA, 1983). It was therefore concluded, probably incorrectly, that detention ponds were ineffective at improving water quality. It is due to the fact that modified detention ponds with extended detention times were not evaluated.

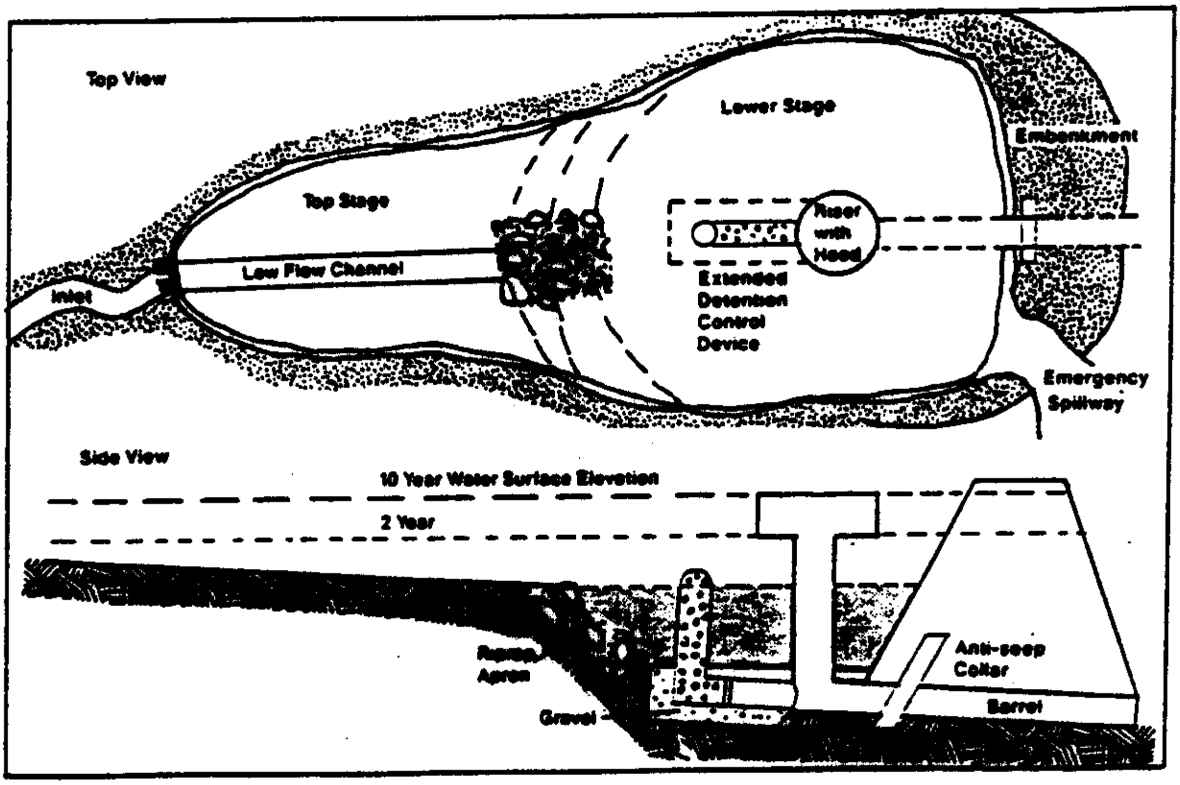

Figure 2. Schematic of Dry Extended Detention Pond (Source: Schueler 1987)

Table I

Pollutant Removal With Respect to Detention Time

Pollutants	% Removed 12 hours	% Removed 24 hours	% Removed 48 hours
TSS	66	75	92
Pb	74	81	85
Zn	44	43	48
COD	34	40	52
TP	44	46	52
TN	24	31	33

Schueler (1987) suggests that a minimum detention time of twenty-four hours is needed for efficient removal of suspended solids and particulate bound contaminates. Grizzard (1986) also suggests a target detention of twenty-four hours, for the average storage time of all storms occurring in any given year, be used for design. To meet this requirement, a design value of approximately forty hours is suggested for the maximum detention time, for the maximum designed detention volume (Grizzard 1986). It should also be noted that through the detaining of all storms, increased pollutant removal will occur. The detaining of small storms, (which would have typically passed through the pond) will have a dramatic effect on reducing the pollutant loading entering adjacent water bodies, thereby, improving overall water quality.

Site suitability is very important in the selection of any best management practice. In this regard, (extended) detention ponds should not be recommended as a best management practice for development sites of less than ten acres (Schueler 1987). Some engineers indicate that development sites of twenty acres or more are more suitable for using (extended) detention ponds as a best management practice.

Other factors that should be considered are soil classification, water table, and depth to bedrock. Some soils are prone to erosion and scour. These soils should be avoided in designing of detention ponds. A detention pond is designed to be dry prior to storm events. If high groundwater tables exist then the pond may not ever be dry. Wet conditions tend to increase the possibility of causing odors and mosquito breeding grounds. The depth to the bedrock is important because of the high cost of rock excavation.

The advantages of using (extended) detention ponds as best management practices are that water quantity can be stored and released at controlled rates and that water quality can be enhanced. A disadvantage of using a detention pond is that the controlled release rates, if improperly planned or designed, can cause downstream flooding during frequently occurring storm events. This is due to the fact that upstream, less developed areas, have longer times of concentration and therefore the time to the peak flow rate is offset (American Society of Civil Engineers (ASCE) Water Forum 1992 - McEnroe (1992), Traver (1992), George (1992)). Another disadvantage is that extended detention ponds, due to improper or lack of maintenance, can become a nuisance. The nuisance can involve unpleasant odors, mosquito breeding, or in general, a diminished aesthetic appeal.

Retention Ponds

Retention ponds act as a permanent storm water management structure, with the primary purpose to permanently store a given volume of storm water runoff (SC LRCC 1992). A retention pond has a permanent storage pool that is always wet, even when a storm event is not occurring and a temporary storage pool for storm water (see Figure 3). When a storm event occurs, storm water runoff will temporarily be stored and then released at a controlled rate.

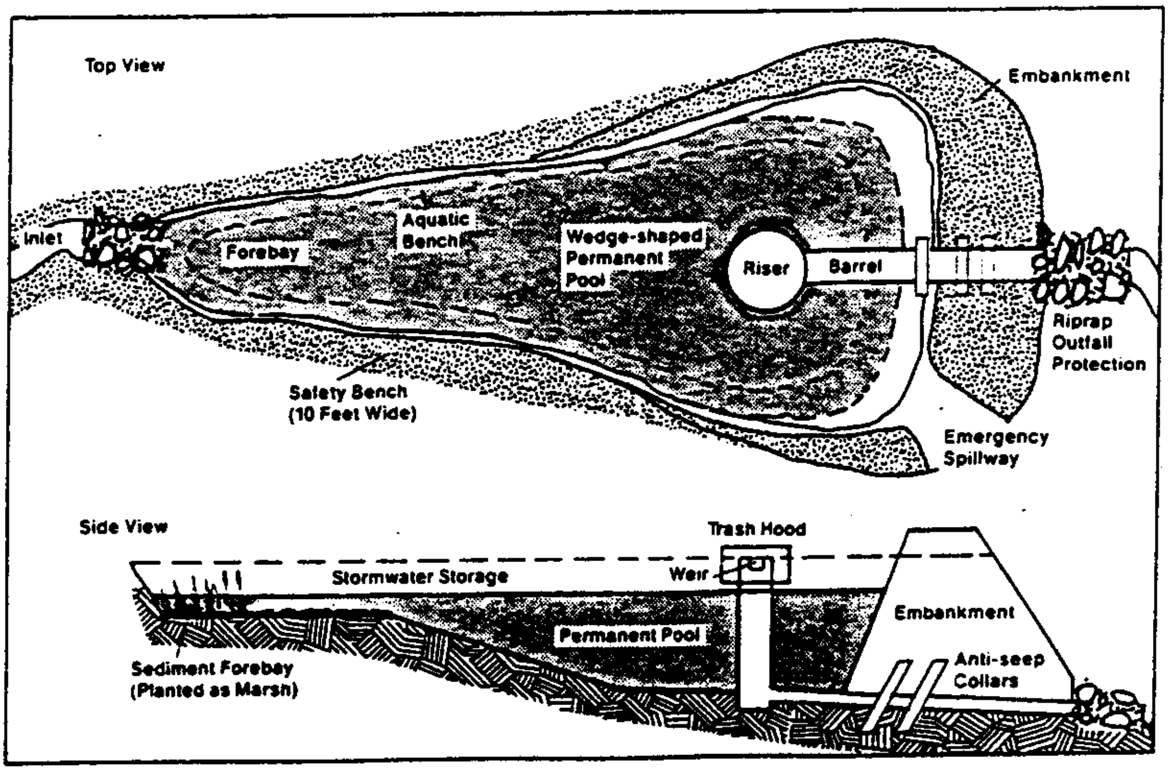

Figure 3. Schematic of Retention Pond
(Source: Schueler 1987)

An optimal retention pond design performs as a multipurpose best management practice which controls storm water runoff discharges, improves water quality, and provides habitats for both plants and animals. Retention ponds can attain a high removal rate of sediment, BOD, organic nutrients, and trace metals. With the much longer detention times associated with retention ponds, algae and aquatic plants thrive and remove ammonia, nitrate, and orthophosphate. These soluble nutrients are converted to biomass and eventually settle out. Detention ponds tend to have shorter storage times, thus less algae and aquatic plants are available to remove soluble nutrients (Schueler 1987).

The basic theory behind the design and development of retention ponds is that storm water runoff enters the pond and is stored. The previously stored runoff water, which was "treated" through, settling, adsorption, or biological uptake, is then forced out of the basin by the incoming runoff waters. This is not always the case. If the flow distance between the inlet(s) and outlet(s) are not sufficiently great, then short circuiting of the pond can occur and treatment of the storm water runoff will be ineffective. This problem can be eliminated if pond designs are "wedge" shaped (Schueler 1987). This is also true for detention ponds

NURP recorded that predicted long term efficiencies of retention ponds ranged from excellent to very poor (USEPA 1983). NURP indicates if the retention ponds were properly designed (sized), that total suspended solids and lead removals were achieved in excess of 90%. Pollutants with high soluble fractions showed lower removal rates, on the order of 65% for total phosphorous (TP), and approximately 50% for BOD, COD, total Kjeldahl nitrogen (TKN), copper, and zinc.

Surveys show that residents prefer retention ponds over detention ponds by a 3 to 1 margin (Adams 1983). In other surveys, residents found retention ponds improved the aesthetics of the community, which thereby enhanced property values (Baxter 1985).

The biggest disadvantage associated with retention ponds is the liability associated with the safety of the pond. The pond could be considered as an "attractive nuisance." An attractive nuisance is defined as anything that could attract a child; a lake, pond, pool, play area, etc. The cause of harm to the child need not be the attractive nuisance (Chapman 1992). Some municipalities require that retention ponds be fenced to protect children from drowning. This however reduces some of the aesthetic value of the pond. Schueler suggest's some guidelines to minimize the risk of accidental drowning (Schueler 1987):

- fence off large diameter outlets
- avoid sharp drop offs near shorelines
- install under water safety bench
- pond depths should be kept relatively shallow.

Other disadvantages are similar to those associated with detention ponds, in that flooding could occur downstream even at frequently occurring design storms, and the lack of funds for proper maintenance. A considerable disadvantage, is that sediment removal from retention ponds is very expensive. The sediment must be dredged, then allowed to dewater.

Disadvantages also include the raising of downstream temperature and the depletion of dissolved oxygen (DO). Retention ponds' large surface area and storage volume facilitate faster heating which supports faster algae growth and decay which depletes dissolved oxygen. During the warmer summer months, one study determined that downstream receiving water temperature had increased as much as 10 to 11°F (5.6 to 6.1°C) because of retention ponds (Galli 1986). This temperature rise can cause severe stress or kill temperature sensitive aquatic life (i.e. trout). To counteract the effect of raising the water temperature, outfalls can be constructed so that the cooler bottom water is discharged. In coastal regions, topography are very flat and bottom water discharges will not always be feasible. Another means of cooling water temperature is to landscape the basin (discussed later in "Vegetation Systems - Basin Landscaping") with trees and shrubs to provide shade to the pond. Shading around the pond, however, will reduce algal growth which in turn could reduce nutrient removal.

Dissolved oxygen can be periodically depleted during the summer months if eutrophication occurs. The end result is that algae take up all the dissolved oxygen and anoxic waters are discharged. Downstream aquatic life will be drastically altered until atmospheric aeration increases the dissolved oxygen to normal levels (Galli 1986 and Free and Mulamootil 1983). A suggestion to alleviate this problem is to add a fountain or aerator system to the pond (Schueler 1987).

Infiltration Basins

Infiltration basins capture and store runoff, and then allows the storm water to infiltrate into the ground or to be evaporated. Infiltration basins, like detention ponds, are typically dry before a storm event. However, infiltration basins have a much longer holding time than detention ponds. This is due to the fact that infiltration basins remove storm water runoff by exfiltration and detention ponds release the storm water runoff with a controlled outlet structure. Exfiltration is the downward movement of storm water runoff through the soil profile (Schueler 1987). Infiltration basins and retention ponds are similarly effective at recharging groundwater.

Infiltration basins can be an extremely efficient best management practice to improve water quality but require regular maintenance. Regular maintenance for any infiltration best management practice is required but is an absolute must for infiltration basins because of high failure rates. Similar to an infiltration trench, an infiltration basin should have a vegetative filter strip (see "Vegetative Systems - Filter Strips") that remove coarse sediments, trash, and other debris. Infiltration basins are typically designed to contain the entire runoff of the 2 year design storm (see Figure 4). The drainage area, when an infiltration basin is used as a best management practice, should typically be no greater than about 50 acres (Schueler 1987). The soils should again have moderate to high permeability, and the bedrock and water table should be located at a minimum of 2 to 4 feet from the bottom of the infiltration basin.

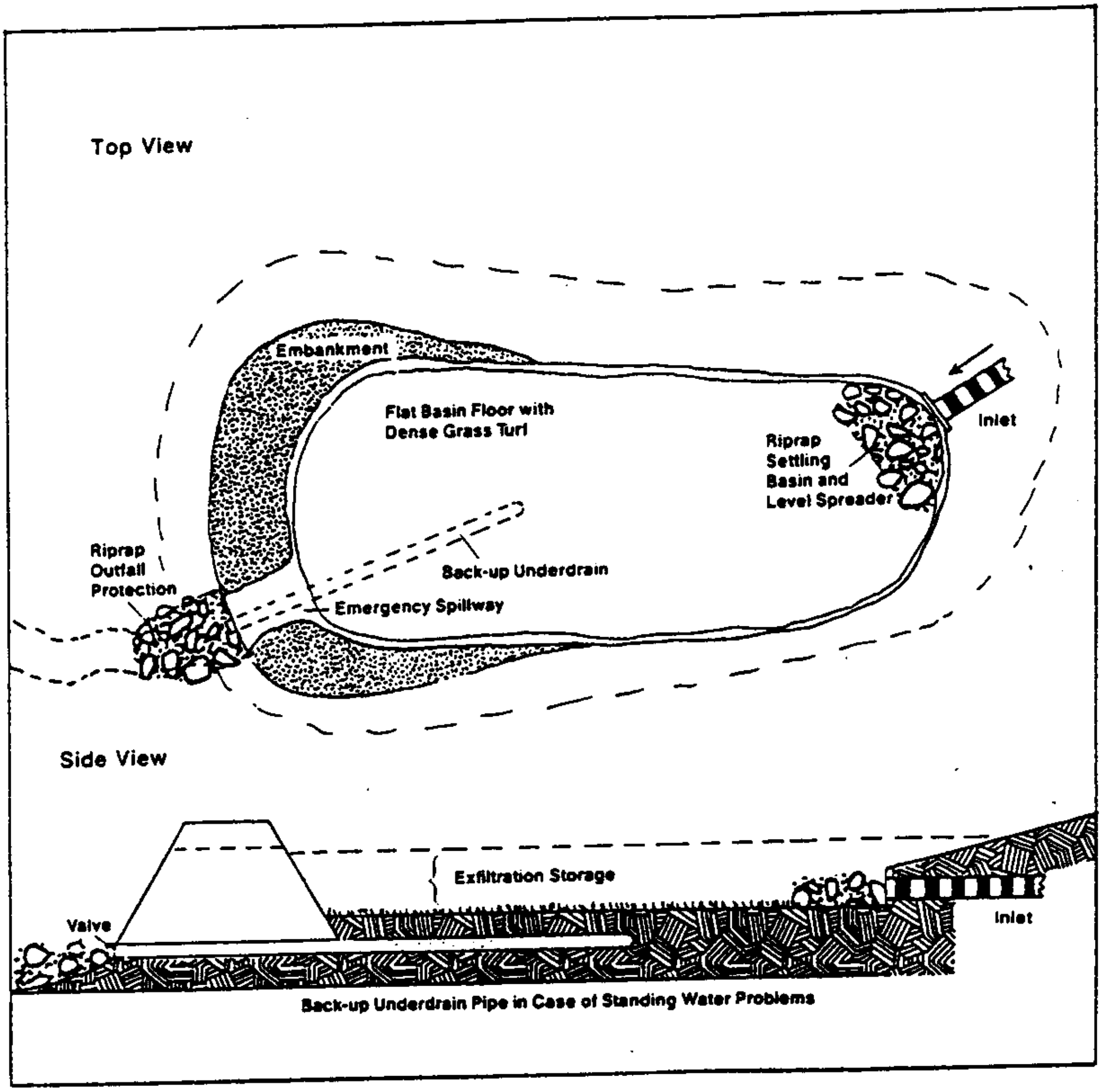

Figure 4. Schematic of Infiltration Basin
(Source: Schueler 1987)

Current design practice dictates that an emergency spillway and backup under-drain be included in the design of the infiltration basin. The emergency spillway allows runoff volumes generated greater than the two year design storm to pass on through the basin. The backup under-drain allows the basin to be drained if infiltration capacity of the basin fails (i.e. runoff is taking to long to exfiltrate). Common design practices also dictate that a minimum infiltration time of six hours is needed but the infiltration time should be no greater than seventy-two hours. This is so that proper pollutant removal can be achieved and so that the basin will not become a community nuisance (i.e. odors, mosquitos, etc.).

Another common design practice is to have the bottom slope of the basin as close as possible to zero. This maximizes the surface area for infiltration to occur and does not promote premature clogging in a lower lying area. Flow at the inlet should also be controlled by energy dissipators so that erosive velocities are avoided, which could lead to scour and/or re-suspension of pollutants (Schueler 1987).

The establishment of water tolerant turf grass is critical to the success of the infiltration basin. The turf grass maintains infiltration capacity, keeps accumulated pollutants from being re-suspended, and adsorbs soluble pollutants. The removal mechanisms used by infiltration basins are sorption, trapping, straining, precipitation, and bacterial degradation or transformation (Schueler 1987).

NURP did not report efficiencies for infiltration basins but indicated that recharge management practices were capable of providing very effective pollutant removal (USEPA 1983). Schueler (1987) estimates the long term removal rate (for the two year runoff volume) to be 99% for sediment, 65 to 75% for total phosphorous, 60 to 70% for total nitrogen, 95 to 99% trace metals, 90% for BOD, and 98% for bacteria. These estimates are based on field testing of rapid infiltration land treatment systems conducted by NVPDC (1979) and USEPA (1977).

Infiltration basins have several different variations of the basic design.

- Full Infiltration Basin Design (Fig. 3)
- Combined Infiltration/Detention Basin Design (Fig. 4)
- Side-by-Side Basin Design (Fig. 5)
- Off-Line Infiltration Basin Design (Fig. 6)

Advantages of infiltration basins are: efficient removal of pollutants, sedimentation basins in the construction phase (must then be regraded), recharge groundwater, and protection of downstream aquatic life (by maintaining pre-development baseflows even during the low flows associated with summer months). Disadvantages are the relatively high failure rate, the risk of groundwater contamination, and the aesthetically displeasing attributes a failed basin can have on a community. High failure rates are from inadequate designs, improper maintenance, or site conditions proving to be unsuitable for infiltration.